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AEDC-TR-66-186



# PERFORMANCE OF THE AEROJET-GENERAL CORPORATION ALCOR 1B SOLID-PROPELLANT ROCKET MOTOR UNDER THE COMBINED EFFECTS OF ROTATIONAL SPIN AND SIMULATED ALTITUDE

L. R. Bahor
ARO, Inc.

October 1966

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**ROCKET TEST FACILITY**
**ARNOLD ENGINEERING DEVELOPMENT CENTER**
**AIR FORCE SYSTEMS COMMAND**
**ARNOLD AIR FORCE STATION, TENNESSEE**

# NOTICES

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## FOREWORD

The test program reported herein was conducted at the request of the Ballistic Systems Division (BSD) (BSRPT), Air Force Systems Command (AFSC), for the Aerojet-General Corporation under Program Element 64406124, System 627A.

The results of the tests were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), AFSC, Arnold Air Force Station, Tennessee, under Contract AF40(600)-1200. The test was conducted in Propulsion Engine Test Cell (T-3) of the Rocket Test Facility (RTF) on July 20, 1966, under ARO Project No. RC0638, and the manuscript was submitted for publication on September 1, 1966.

This technical report has been reviewed and is approved.

John W. Hitchcock
Major, USAF
AF Representative, RTF
Directorate of Test

Leonard T. Glaser
Colonel, USAF
Director of Test

## ABSTRACT

One Aerojet-General Corporation, Alcor 1B, solid-propellant rocket motor was successfully tested at an average simulated altitude of 100,000 ft while spinning about its axial centerline at an average spin rate of 304.3 rpm. The objective of this test was to evaluate the ballistic performance, tailoff characteristics, and structural integrity of the flightweight motor assembly under the combined effects of rotational spin and near-vacuum environment. The vacuum total impulse was 256,616 $lb_f$-sec; the vacuum specific impulse, based on the vacuum total impulse and pre- and post-fire weight difference, was 279.12 $lb_f$-sec/$lb_m$. The total burn time, defined as the time interval from the application of voltage to the igniter to the time when the chamber pressure-to-cell pressure ratio is 1.3, was 35.30 sec.

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## NOMENCLATURE

| | |
|---|---|
| $A_{ex}$ | Nozzle exit area |
| $A_{th}$ | Nozzle throat area |
| $c_f$ | Vacuum thrust coefficient |
| F | Measured axial thrust |
| $F_{vac}$ | Vacuum corrected axial thrust |
| $I_{vac_{action}}$ | Vacuum corrected impulse based on action time |
| $I_{vac_{critical}}$ | Vacuum corrected impulse based on critical time |
| $I_{vac_{total}}$ | Vacuum corrected impulse based on total time |
| $P_{cell}$ | Measured cell pressure |
| $P_{ch}$ | Measured chamber pressure |
| $t_a$ | Time from 100-psia chamber pressure at ignition to 100-psia chamber pressure at tailoff |
| $t_{bd}$ | Time of nozzle flow breakdown |
| $t_c$ | Time from $t_o$ to 30-psia chamber pressure at tailoff |
| $t_d$ | Time from $t_o$ to 100-psia chamber pressure at ignition |
| $t_o$ | Time of application of voltage to the igniter |
| $t_t$ | Time from first indication of thrust or chamber pressure until curve decays to zero |

# SECTION I
# INTRODUCTION

The four-stage, partially guided, Athena booster is a solid-propellant re-entry test vehicle used to place a payload at a designated point in space and at certain specified conditions so that useful re-entry experiments may be performed.

The vehicle consists of first- and second-stage boosters and a re-entry package consisting of the third and fourth stages and the payload. The third and fourth stages of the vehicle are used to drive a 50-$lb_m$ payload back into the atmosphere at a speed of about 22,000 ft/sec. Staging is controlled by a time sequence based on the predicted performance of each motor, whereas the trajectory and impact point are dependent on in-flight ballistic performance (Ref. 1).

The data from the most recent static test firing of the Alcor 1B motor indicated an abnormally long tailoff. Consequently, a test program was conducted to document the tailoff characteristics and ballistic performance of the Aerojet Alcor 1B when fired under the combined effects of simulated altitude and 300-rpm rotational spin.

One Aerojet Alcor 1B, solid-propellant rocket motor was fired at an average simulated altitude of 100,000 ft while rotating about its axial centerline at approximately 300 rpm. Ignition and tailoff characteristics are discussed along with motor ballistic performance.

# SECTION II
# APPARATUS

## 2.1 TEST ARTICLE

The Aerojet Alcor 1B, solid-propellant rocket motor (Fig. 1) has a titanium alloy case (proof-pressure from 645 to 650 psi) with a nominal outside diameter of 20.52 in. and a length of 55.16 in. The overall length of the motor with the 16.3:1 area ratio nozzle installed is 76.10 in. The motor case is insulated throughout with 0.075-in.-thick Elastomer Gen-Gard V-44 and V-45 rubber.

The Aerojet Alcor 1B (Fig. 1a) is loaded with 913.7 $lb_m$ of Aerojet ANB-3066 Type III Polybutadiene propellant. The propellant is cast in a modified 6-point-star configuration with the star points every 60 deg.

The loaded motor weighs approximately 1000 $lb_m$. Nominal motor performance is: thrust, 10,000 lbf; chamber pressure, 528 psia; and action time, 25.6 sec.

The 16.3:1 area ratio contoured nozzle has a nominal exit half-angle of 14 deg. The glass roving, epoxy-impregnated nozzle exit cone is attached to the motor case by means of a 4130 steel adapter flange. The nozzle is insulated internally with silica phenolic tape. The ATJ graphite throat insert has an area of 13.39 in.$^2$.

Ignition was accomplished by an igniter (Fig. 2), which contains a main charge of Alclo pellets weighing nominally 120 gm. The igniter incorporates four Bermite 400735 squibs in two parallel sets. Each set contains two squibs in parallel. The squibs are used to ignite an initiator charge of boron and potassium nitrate (BPN) powder. The igniter charge is contained in a honeycomb-like tube overwrapped with polyester tape. The total igniter weight, including charges, is 1.9 $lb_m$. The igniter contained ports to house chamber pressure transducers.

Since the nozzle did not contain a closure, motor chamber pressure was equal to cell pressure at ignition.

## 2.2 INSTALLATION

The motor was installed in Propulsion Engine Test Cell (T-3) (Ref. 2) in a spin fixture assembly mounted on a thrust cradle, which was supported from the cradle support stand by three vertical and two horizontal double-flexure columns (Fig. 3). The spin fixture assembly consisted of a 10-hp squirrel-cage-type drive motor, a forward thrust bearing assembly, a drive shaft and thrust pylon, and an aft bearing assembly. Electrical leads to and from the igniter, pressure transducers, and thermocouples on the rotating motor were provided through a 52-channel slip-ring assembly mounted on the drive shaft. Axial thrust was transmitted through the drive shaft-thrust bearing assembly to two double-bridge load cells mounted just forward of the thrust bearing.

Pre-ignition pressure altitude conditions were maintained in the test cell by a steam ejector operating in series with the RTF exhaust compressors. During the motor firing, the motor exhaust gases were used as the driving gas for the 47.25-in.-diam, ejector-diffuser system to maintain test cell pressure at an acceptable level.

## 2.3 INSTRUMENTATION

Instrumentation was provided to measure axial thrust, test cell pressure, motor chamber pressure, motor case and grain temperatures, and motor rotational speed. Table I presents instrument ranges, recording methods, and system accuracies for all measured parameters.

The axial thrust measuring system consisted of two double-bridge, strain-gage-type load cells mounted in the axial double-flexure column forward of the thrust bearing on the rocket motor centerline. Unbonded strain-gage-type transducers (0- to 1-psia) were used to measure test cell pressure. Bonded strain-gage-type transducers in ranges from 0 to 15, 0 to 30, and 0 to 750 psia were used to measure motor chamber pressure. Iron-Constantan (IC) thermocouples were bonded to the motor case (Fig. 4) to measure outer surface temperatures during and after motor burn time. In addition, thermocouples were taped to the propellant grain to measure pre-fire grain temperature.

Rotational speed of the motor and spin rig assembly was determined from the output of a magnetic pickup.

The output signal of each measuring device was recorded on independent instrumentation channels. Ballistic data were obtained from four axial thrust channels, two high range (0- to 750-psia) and two low range (0- to 30- and 0- to 15-psia) motor chamber pressure channels, and three test cell pressure channels. These data were recorded as follows: Each instrument output signal was indicated in totalized digital form on a visual readout of a millivolt-to-frequency converter. A magnetic tape system, recording in frequency form, stored the signal from the converter for reduction at a later time by an electronic digital computer.

The output signal from the magnetic rotational speed pickup was recorded and displayed on visual indicators in the following manner: A frequency-to-analog converter was triggered by the pulse output from the magnetic pickup and in turn supplied a square wave of constant amplitude to the electronic counter, magnetic tape, and oscillograph recorders. The scan sequence of the electronic counter was adjusted so that it displayed directly the motor spin rate in revolutions per minute.

The millivolt outputs of the thermocouples were recorded on magnetic tape from a multi-input, high speed, analog-to-digital converter at a scan rate for each thermocouple of 6.66 times/sec. A photographically recording, galvanometer-type oscillograph provided an independent backup of all operating instrumentation channels.

Selected channels of thrust, pressures, and temperatures were recorded on null-balance, potentiometer-type strip charts for analysis immediately after the motor firing. Visual observation of the firing was provided by a closed-circuit television monitor. High speed, motion-picture cameras provided a permanent visual record of the firing.

## 2.4 CALIBRATION

The thrust calibrator weights, thrust load cells, and pressure transducers were laboratory-calibrated prior to usage in this test. After installation of the measuring devices in the test cell, all systems were calibrated at sea-level ambient conditions and again at pressure altitude conditions after the 300-rpm rotative speed was attained.

The pressure systems were calibrated by an electrical, four-step calibration, using resistances in the transducer circuits to simulate selected pressure levels. The axial thrust instrumentation systems were calibrated by applying to the thrust cradle known forces which were produced by the deadweights acting through a bell crank. The calibrator is hydraulically actuated and remotely operated from the control room.

After the motor firing, with the motor spinning at simulated altitude, the systems were re-calibrated to determine if any shift had occurred.

# SECTION III
# PROCEDURE

The Aerojet General Corporation, Alcor 1B (S/N STV097), solid-propellant rocket motor arrived at AEDC on July 1, 1966. The motor was visually inspected for possible shipping damage and radiographically inspected for grain cracks, voids, or separation and found to meet criteria provided by the manufacturer. During storage in an area temperature conditioned at 80 ± 5°F, the motor was checked to ensure correct fit of mating hardware, the electrical resistance of the igniter was measured, the nozzle throat and exit diameters were obtained, thermocouples were bonded to the grain and motor case, and the entire motor assembly was weighed. Before installation in the test cell, the motor was temperature-conditioned at 80 ± 5°F for a minimum of 48 hr.

After installation of the motor in the test cell, the cell temperature conditioning system was adjusted to maintain the cell temperature at

80 ± 2°F, instrumentation connections were made, and a continuity check of all electrical systems was performed. The motor was spun at sea-level conditions at 300 rpm to ensure proper balance of the spin rig assembly. Pre-fire, sea-level calibrations were completed, the test cell pressure was reduced to the desired simulated altitude condition, and altitude calibrations were accomplished. Spinning of the unit was then started, and after spinning had stabilized at 300 rpm, a complete set of altitude calibrations was taken. The final operation prior to firing was adjustment of the circuit resistance and voltage to provide the desired current to the igniter squibs. The entire instrumentation measuring-recording complex was activated, and the motor was fired while spinning (under power) at 300 rpm. After motor burnout, the 300-rpm spin rate was maintained until post-fire altitude calibrations were accomplished. The unit was then decelerated slowly until rotation had stopped, and an additional set of calibrations was taken. The test cell pressure was returned to ambient conditions, and the motor was inspected, photographed, and removed to the storage area. Post-fire inspections consisted of measuring the nozzle, weighing the motor, and photographically recording the post-fire condition of the motor.

## SECTION IV
## RESULTS AND DISCUSSION

One Aerojet Alcor 1B solid-propellant rocket motor was fired at an average simulated altitude of 100,000 ft while spinning at 300 rpm. Ignition and tailoff characteristics, altitude ballistic performance, structural integrity, and motor temperatures are discussed.

The ballistic performance data obtained are summarized in Table II, and the summary of motor physical dimensions is presented in Table III. When more than one instrumentation channel was used to obtain values of a single parameter, the average of these values was used to calculate the data presented.

The ballistic performance data are presented and evaluated on the basis of parameters defined in Ref. 3. The parameters are defined as follows:

1. Ignition delay time ($t_d$) is defined as the time from application of voltage to the igniter to the time the chamber pressure increases to 100 psia.
2. Action time ($t_a$) is defined as the time interval between the 100-psia points on the rising and decaying portions of the chamber pressure-time curve.

3. Critical time ($t_c$) is the time interval between application of voltage to the igniter and the time when the chamber pressure decays to 30 psia during tailoff.

4. Total time ($t_t$) is the time from the first indication of thrust or chamber pressure until the curve decays to zero.*

5. Maximum thrust ($F_{max_{vac}}$) is the highest thrust developed by the motor during firing.

6. Maximum pressure ($P_{max}$) is the highest chamber pressure developed by the motor during firing.

7. Vacuum critical impulse ($I_{vac_{critical}}$) is the area under the thrust time curve for the duration of critical time ($t_c$).

Tabulated below are the acceptable performance limits stated in Ref. 3:

| Parameter | Value at 80°F | Tolerance |
|---|---|---|
| Vacuum Critical Impulse ($I_{vac_{critical}}$), $lb_f$-sec | 256,500 | ±2670 |
| Maximum Thrust ($F_{max_{vac}}$), $lb_f$ | 13,075 | ±915 |
| Maximum Pressure ($P_{max}$), psia | 640 | --- |
| Action Time ($t_a$), sec | 25.46 | ±1.86 |
| Critical Time ($t_c$), sec | 26.44 | ±2.00 |
| Total Time ($t_t$), sec | 28.38 | ±3.92 |
| Maximum Ignition Delay Time ($t_d$), sec | 0.100 | --- |

## 4.1 IGNITION AND TAILOFF CHARACTERISTICS

The motor was ignited at a pressure altitude of 106,000 ft. The average simulated altitude during the motor action time was 100,000 ft. An analog

*Because nozzle flow becomes unchoked when the ratio of chamber pressure-to-cell pressure decreases to about 1.3, data beyond this point are not representative of vacuum performance of the motor. For this report, total time ($t_t$) is defined as the time from the first indication of chamber pressure until the ratio of chamber pressure-to-cell pressure decreases to 1.3.

trace of thrust and chamber pressure characteristics during motor ignition is presented in Fig. 5. The ignition delay time was 0.035 sec, this is 0.065 sec less than the maximum allowable.

Figure 6 presents variation of measured thrust, chamber pressure, and cell pressure during the firing. Tailoff characteristics are presented in detail in Figs. 7 and 8. Figure 7 presents the tailoff data starting with the increase in cell pressure, indicating that the rocket motor exhaust plume has become unattached from the diffuser duct, and ending at the point when motor chamber pressure decreases to approximately 12 psia. Figure 8 presents the tailoff data starting with a chamber pressure of approximately 12 psia and continuing until the ratio of chamber pressure-to-cell pressure decreases to 1.3 (point at which exhaust flow in the throat becomes subsonic).

Abnormally high cell pressure was experienced during the time interval from the rocket exhaust plume becoming unattached to the diffuser and the re-establishment of the steam ejector's plume. Post-fire inspection of the test cell and water jacket on the diffuser showed that the diffuser water jacket had failed during the firing. Thrust data fluctuations during tailoff (Fig. 6) indicate that the density of the exhaust gases re-entering the test chamber suddenly increased, indicating that water and/or steam was introduced into the system from the diffuser water jacket. Water and steam in combination with the exhaust gases increased the cell pressure to a maximum value of 1.8 psia.

The low range chamber pressure data (Figs. 7 and 8) do not contain inflection points. It is, therefore, concluded that chamber pressure was unaffected by the cell pressure (nozzle remained choked) during the period of high test cell pressure.

The values of the following parameters defined in the previous section were determined to be:

| Parameter | Motor S/N STV 097 | Performance Limits |
|---|---|---|
| Action Time ($t_a$), sec | 25.627 | 23.60 to 27.32 (Specified) |
| Critical Time ($t_c$), sec | 26.692 | 24.44 to 28.44 (Specified) |
| Total Time ($t_t$), sec | 35.30 | 24.46 to 32.30 (Predicted) |

Action and critical times were within the specifications, whereas total time was 3 sec longer than the predicted limits.

## 4.2 BALLISTIC PERFORMANCE

The variations of thrust, chamber pressure, and test cell pressure with time during the motor firing are shown in Fig. 6.

Since the exhaust nozzle does not operate fully expanded at the low chamber pressure encountered during tailoff, the measured thrust data cannot be corrected to vacuum conditions by adding the product of cell pressure integral and nozzle exit area. Therefore, total, critical, and action times were segmented, and the method used to determine vacuum impulse is illustrated in Fig. 9. The exhaust nozzle flow breakdown was considered to have occurred simultaneously with the exhaust diffuser flow breakdown (as indicated by a rapid increase in cell pressure). The flow at the nozzle throat was considered sonic until the ratio of chamber pressure-to-cell pressure had decreased to a value of 1.3.

The vacuum total and critical impulse and the specified limits are tabulated below:

| Parameter | Motor S/N STV 097 | Specified Performance Limits |
|---|---|---|
| Vacuum Critical Impulse, $lb_f$-sec | 255,696 | 253,830 to 259,170 |
| Vacuum Total Impulse, $lb_f$-sec | 256,616 | --- |
| Vacuum Action Impulse, $lb_f$-sec | 254,366 | --- |

The specified performance limits apply only to vacuum critical impulse; however, the vacuum total and action impulse also fall within the specified limit.

The vacuum total specific impulse based on pre- and post-fire motor weight (expended mass including the combustion products deposited in the nozzle exit) was 279.12 $lb_f$-sec/$lb_m$. The vacuum critical impulse based on expended mass was 278.12 $lb_f$-sec/$lb_m$. The average vacuum thrust coefficient based on critical time was 1.733.

## 4.3 STRUCTURAL INTEGRITY AND TEMPERATURE DATA

Motion-picture films of the firing and the post-fire condition of the motor indicate that an unusually large amount of combustion products was deposited on the interior of the nozzle cone near the area of the exit (Fig. 10). Centrifugal forces acting on the deposited molten products of combustion caused the material to flow from the nozzle exit in a direction radial to the axis of rotation. Post-fire inspection of the motor revealed that the nozzle throat area had increased 7.588 percent (Table III) during

motor operation. The nozzle exit area decreased 0.73 percent during motor operation. The structural integrity of the motor case, nozzle, and igniter assemblies appeared to be satisfactory.

Figure 11 presents temperature-time histories from thermocouples located on the motor case. A maximum temperature of 357°F was recorded on the forward dome of the motor chamber at thermocouple position 7 (Figs. 4 and 11a) at approximately 108 sec after ignition. The maximum temperature of 444°F occurred in the cylindrical portion of the motor case at position 5 (Figs. 4 and 11b) at 156 sec after motor ignition.

## SECTION V
## SUMMARY OF RESULTS

The results of testing an Aerojet-General Corporation, Alcor 1B, solid-propellant rocket motor at an average simulated altitude of 100,000 ft, while spinning about the axial centerline at an average rotational speed of 304.3 rpm, are summarized as follows:

1. Satisfactory motor ignition was obtained at a pressure altitude of 106,000 ft. The ignition delay time, defined as the time interval from application of voltage to the igniter to the time the chamber pressure reached 100 psia, was 0.035 sec. The maximum specified ignition delay time is 0.100 sec.

2. The vacuum total impulse was 256,616 $lb_f$-sec. Vacuum critical impulse was 255,696 $lb_f$-sec. Specified limit of vacuum critical impulse is 256,500 ± 2670 $lb_f$-sec. The vacuum specific impulse, based on the vacuum total impulse and the pre- and post-fire weight difference, was 279.12 $lb_f$-sec/$lb_m$.

3. The total time, defined as the time interval from the application of voltage to the igniter to the time that the chamber-to-cell pressure ratio equals 1.3, was 35.30 sec. The specified limit of total time is 28.38 ± 3.925 sec. The critical time, defined as the time interval from application of voltage to the igniter to the time that chamber pressure decreases to 30 psia at tailoff, was 26.692 sec. The specified limit of critical time is 26.44 ± 2.00 sec.

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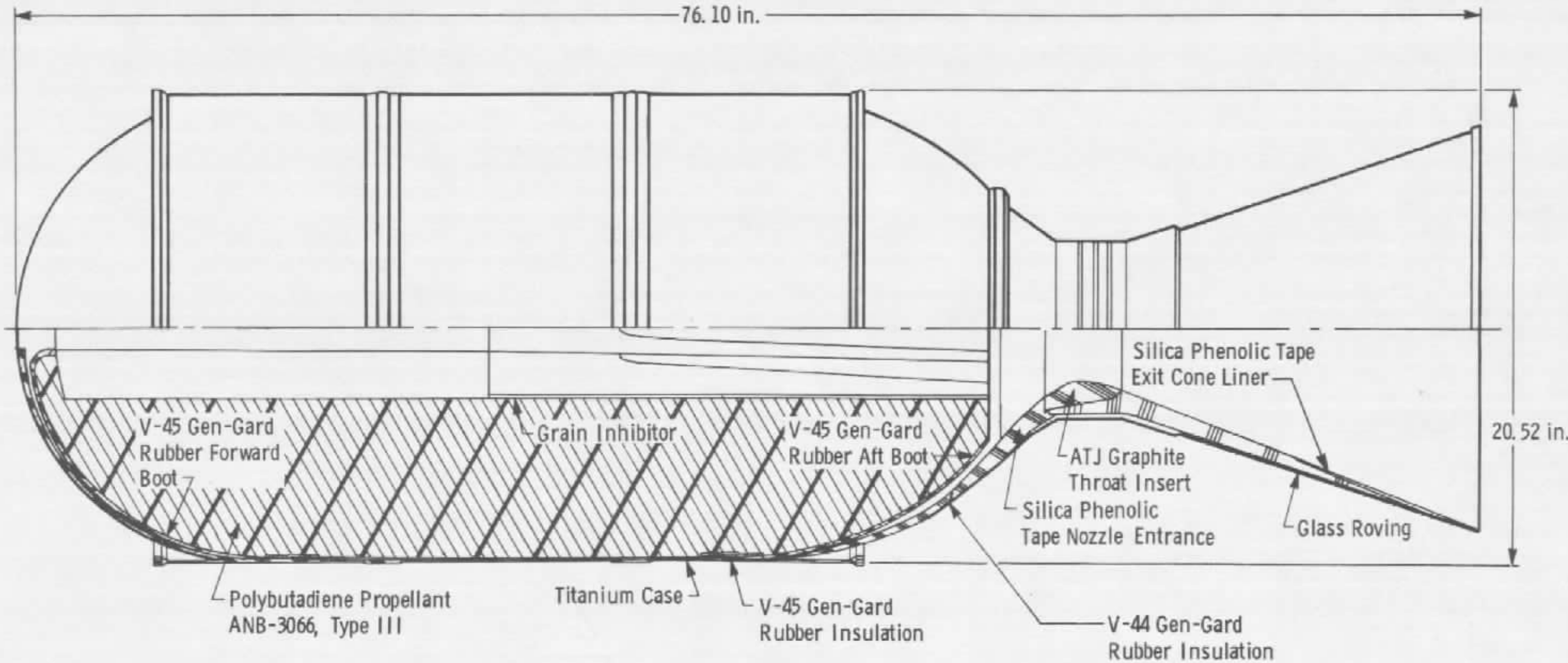
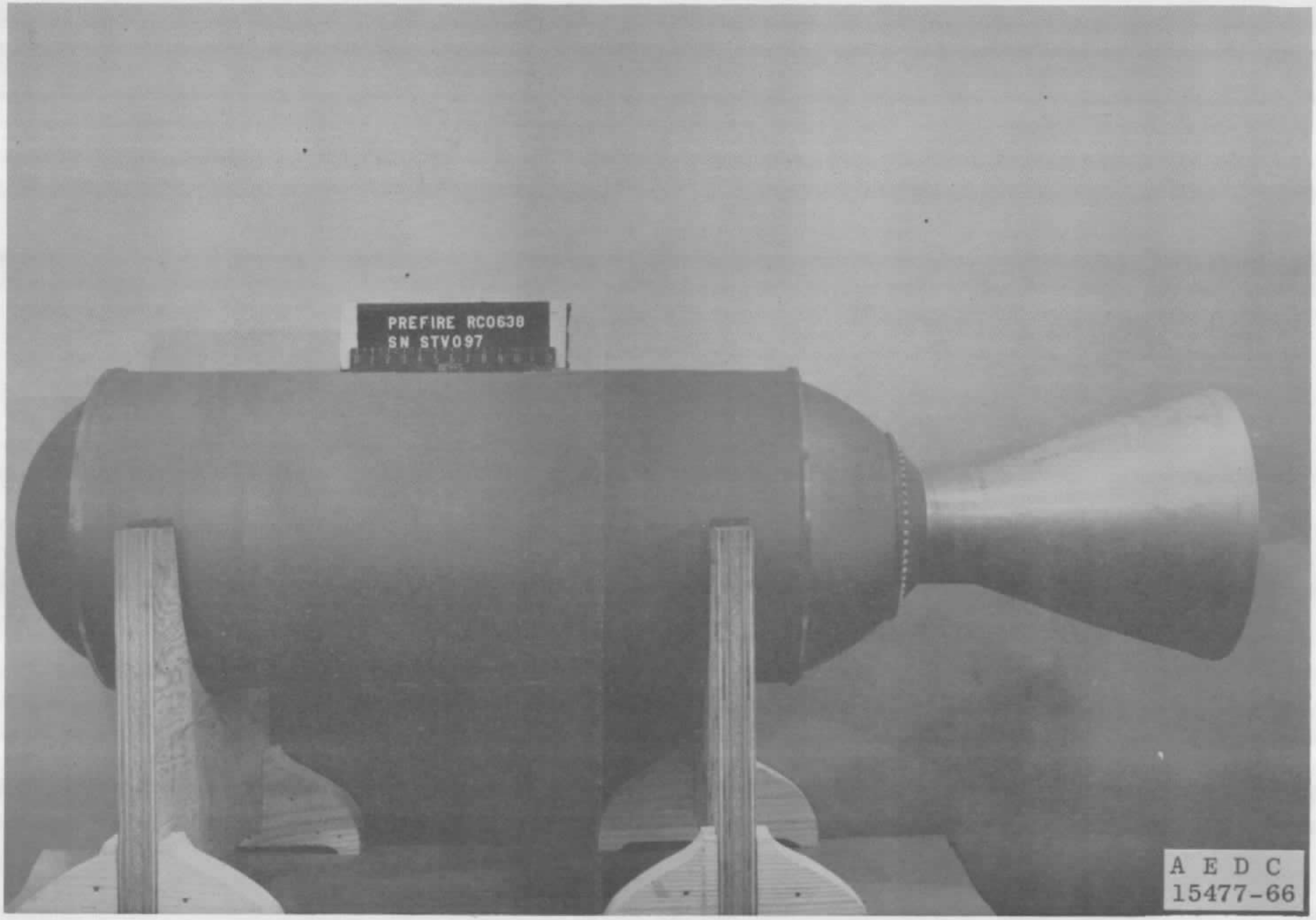
2. Test Facilities Handbook (5th Edition). "Rocket Test Facility, Vol. 2." Arnold Engineering Development Center, July 1963.

3. "Model Specification Rocket Motor, Solid-Propellant Alcor 1B." Contract AF 04(694)-846, BSD Specification CP-23-65-1, March 16, 1966.



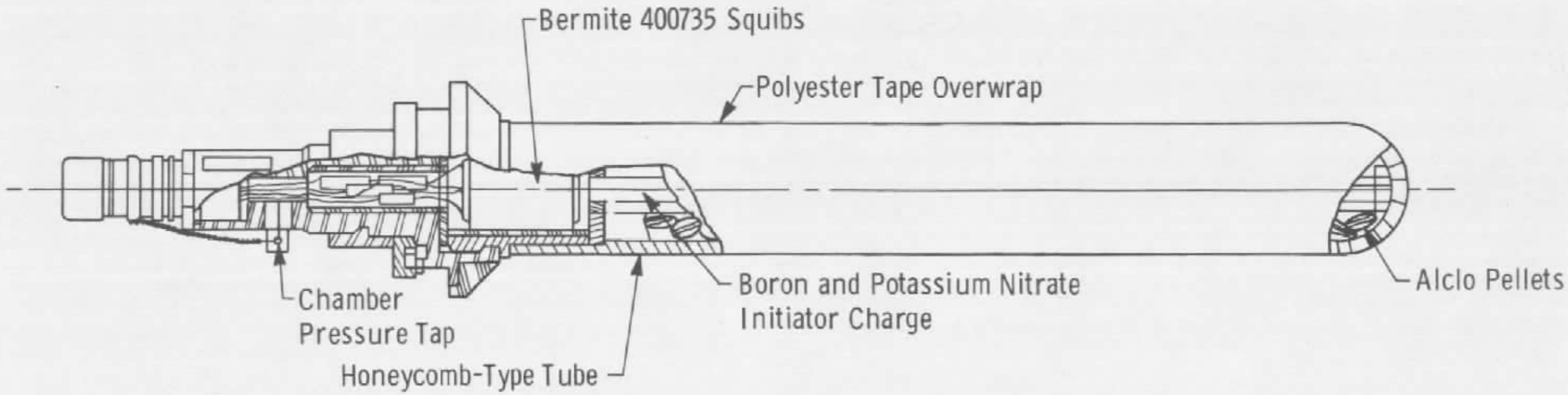

a. Schematic

Fig. 1 Aerojet-General Corporation Alcor 1B Solid-Propellant Rocket Motor



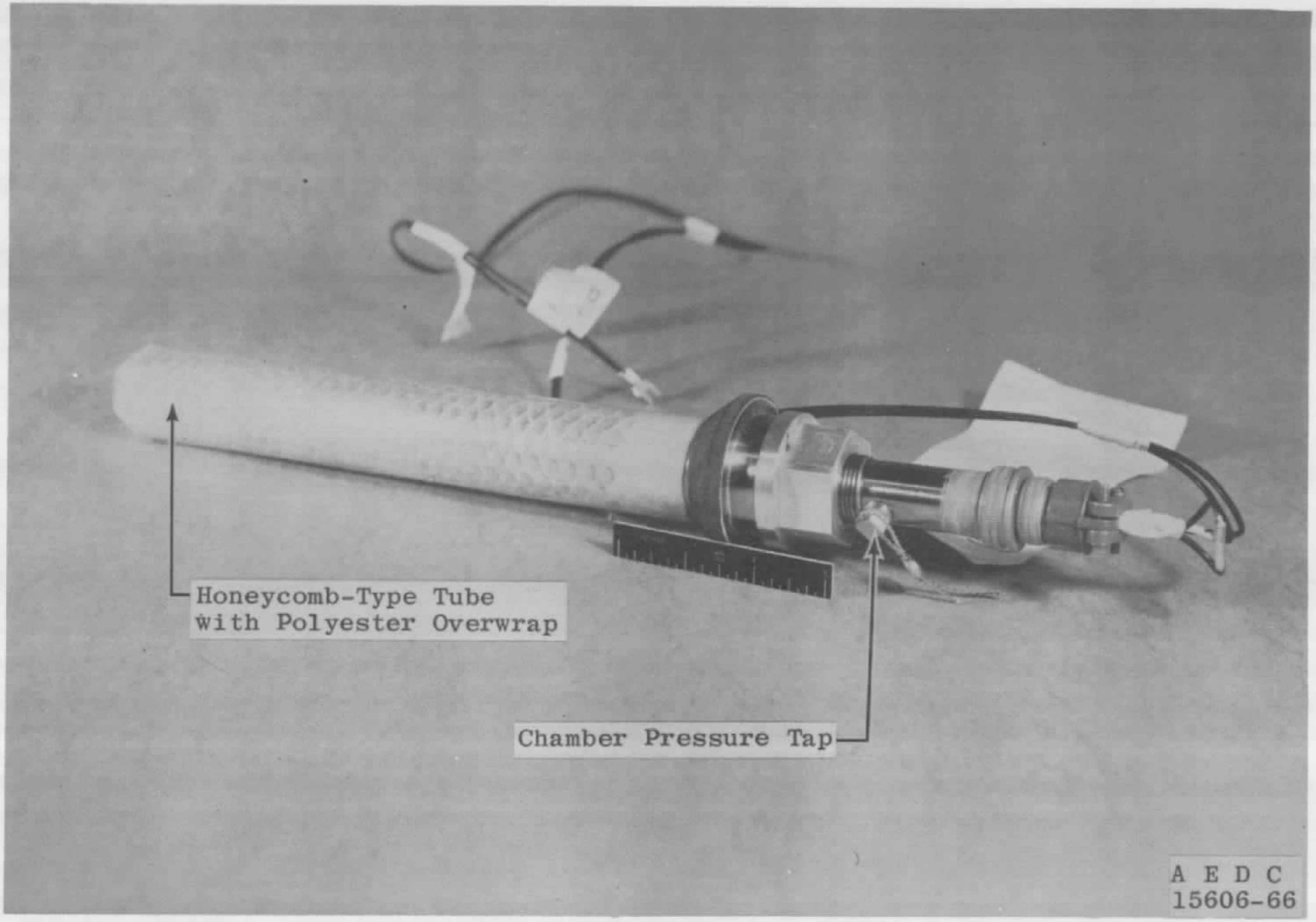

b. Pre-Fire Photograph

Fig. 1 Concluded



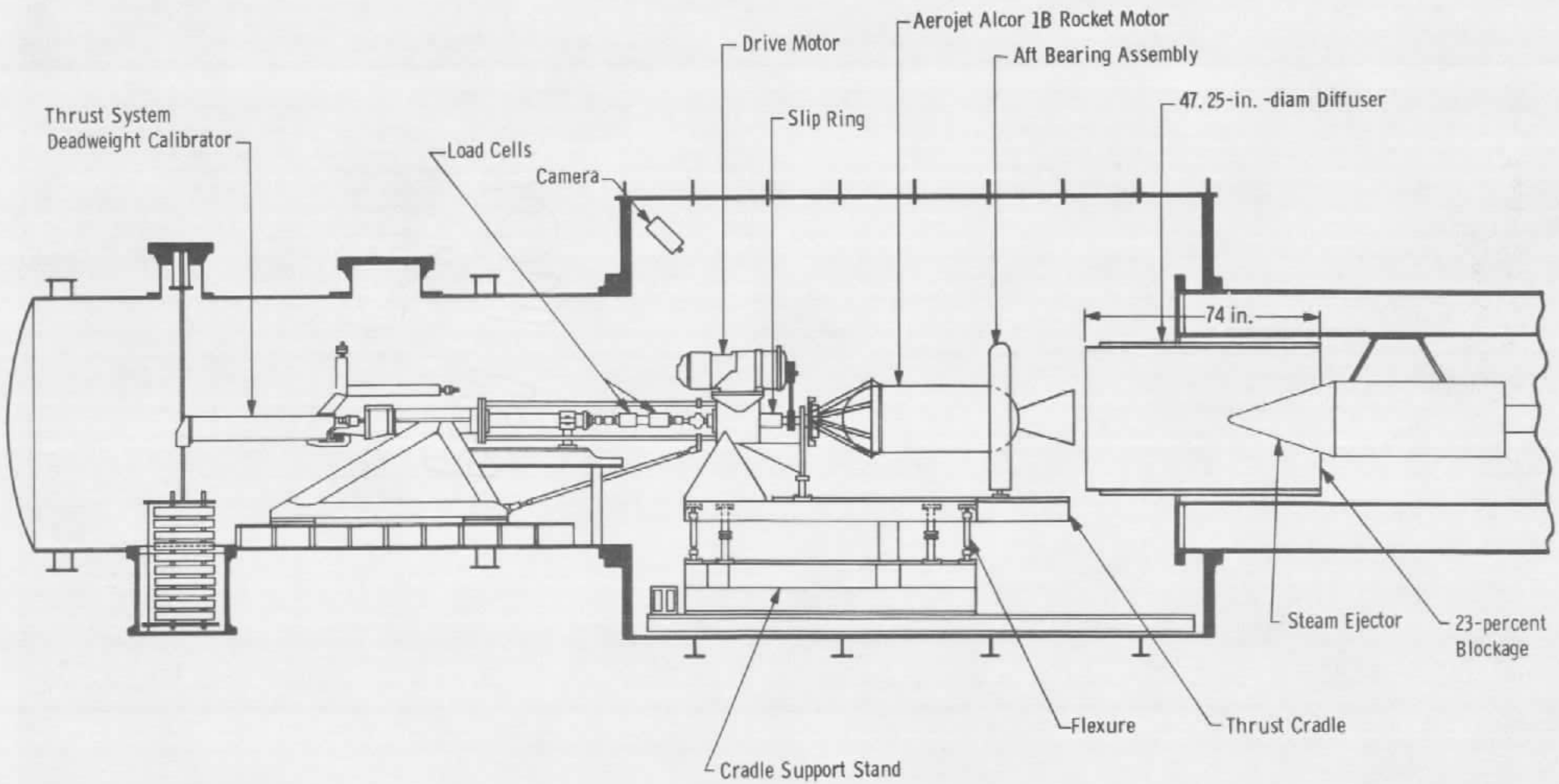

**a. Schematic**

**Fig. 2 Igniter Assembly**



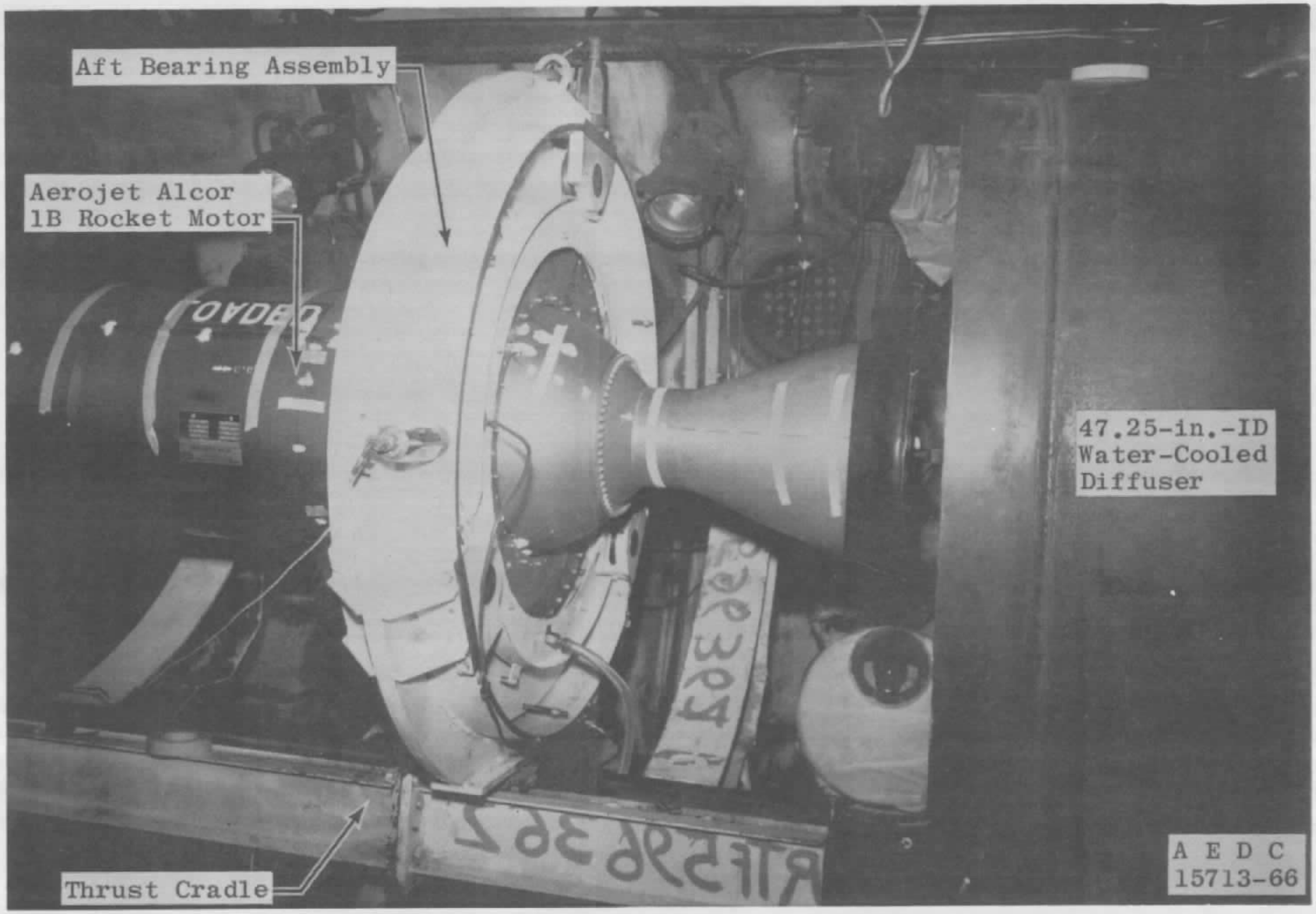

**b. Photograph**

**Fig. 2 Concluded**

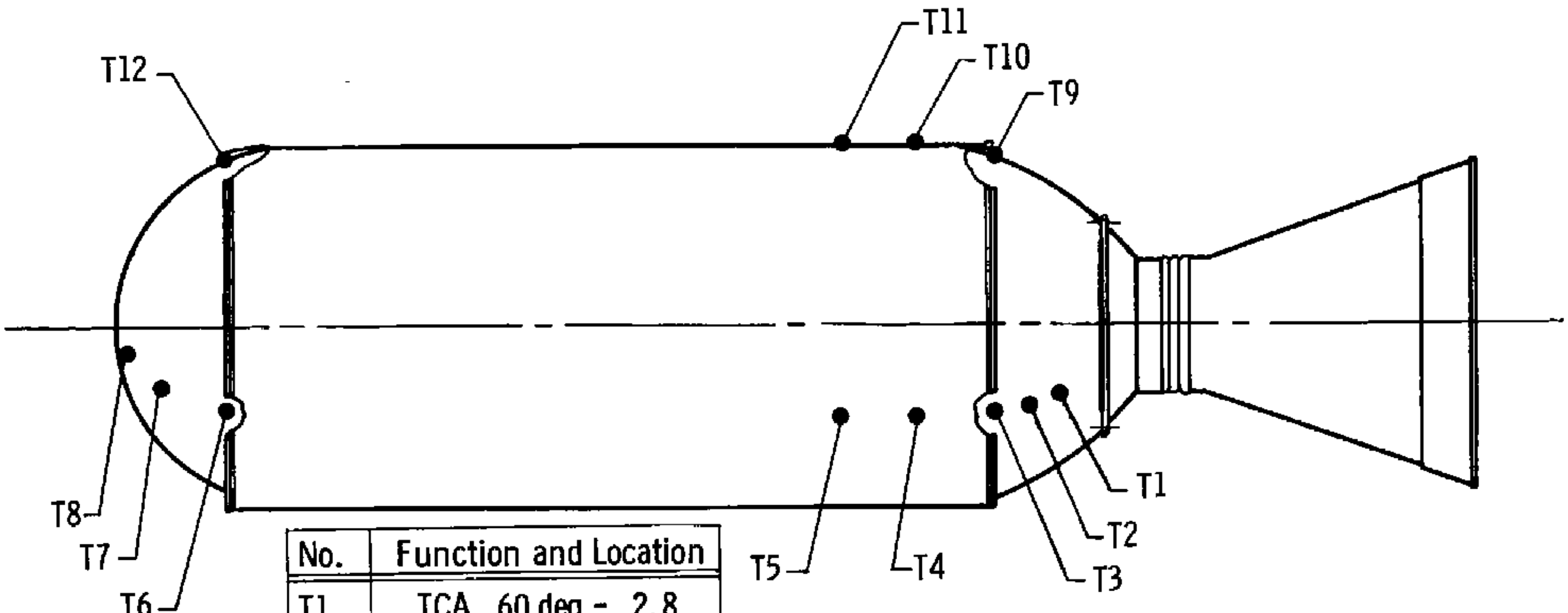



a. Schematic

Fig. 3 Installation of the Alcor 1B Rocket Motor in the T-3 Test Cell




b. Photograph
Fig. 3 Concluded




| No. | Function and Location |
|---|---|
| T1 | TCA 60 deg - 2.8 |
| T2 | TCA 60 deg - 5.0 |
| T3 | TCA 60 deg - 6.8 |
| T4 | TCC 60 deg - 4.4 |
| T5 | TCC 60 deg - 8.7 |
| T6 | TCF 60 deg - 10.5 |
| T7 | TCF 60 deg - 5.9 |
| T8 | TCF 60 deg - 1.9 |
| T9 | TCA 180 deg - 6.8 |
| T10 | TCC 180 deg - 4.4 |
| T11 | TCC 180 deg - 8.7 |
| T12 | TCF 180 deg - 10.5 |

**Fig. 4 Schematic of Thermocouple Locations**

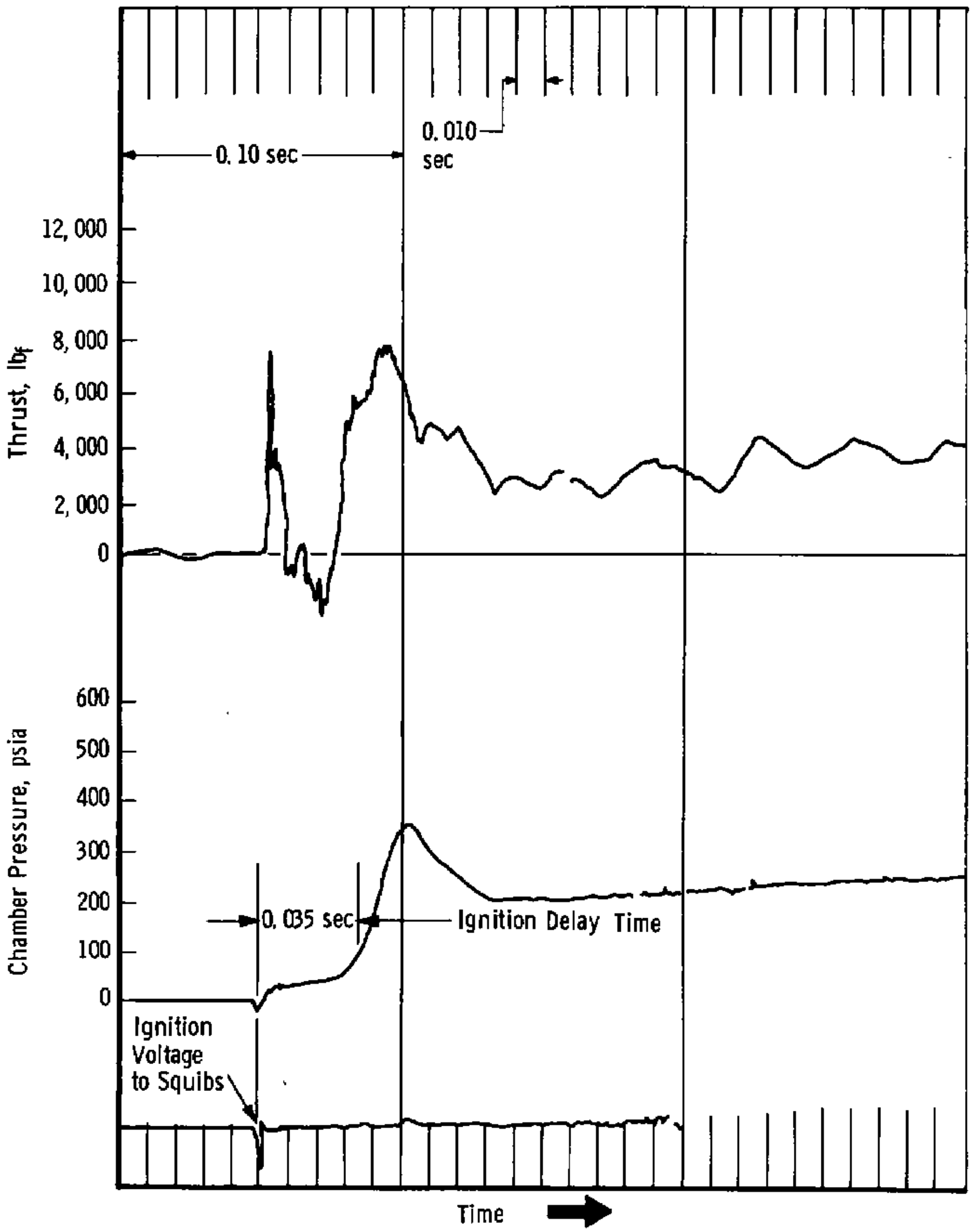



Fig. 5 Analog Trace of Ignition Event

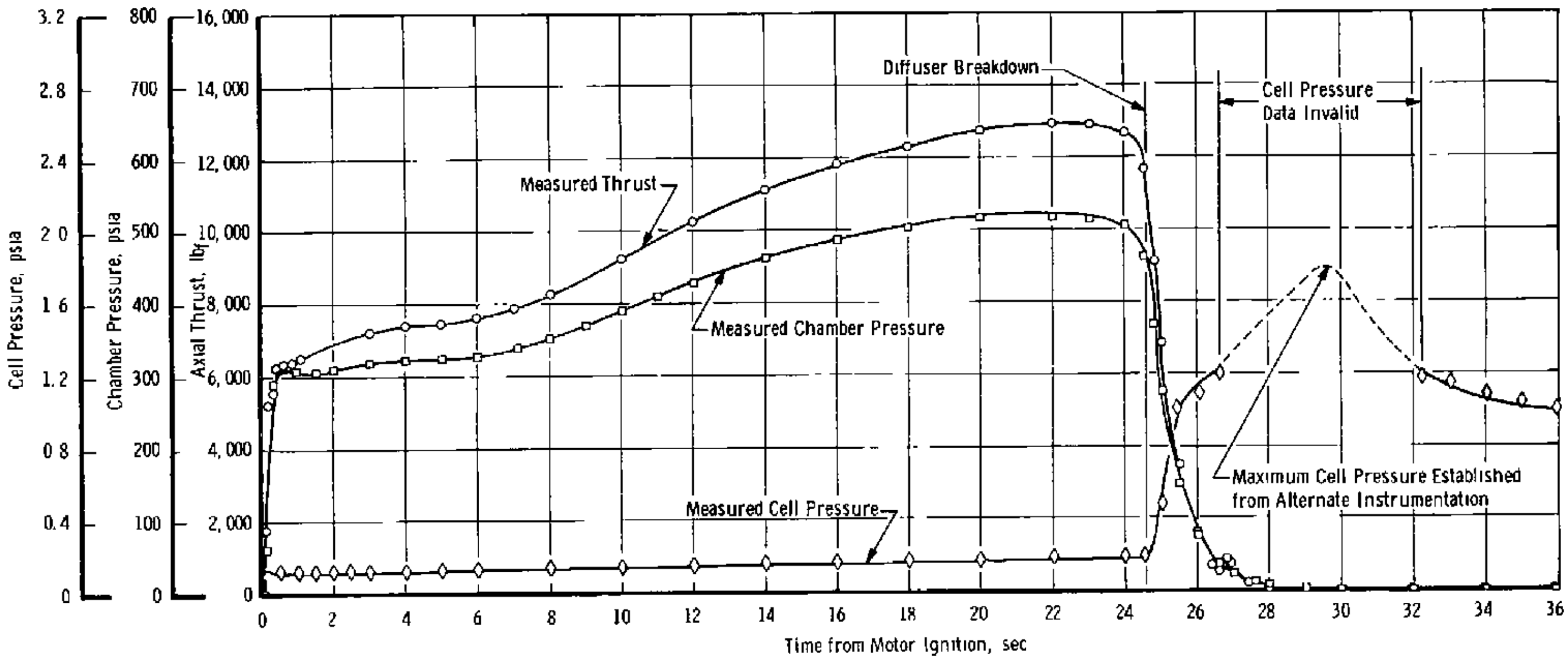



Fig. 6 Variation of Thrust, Chamber Pressure, and Cell Pressure during Firing

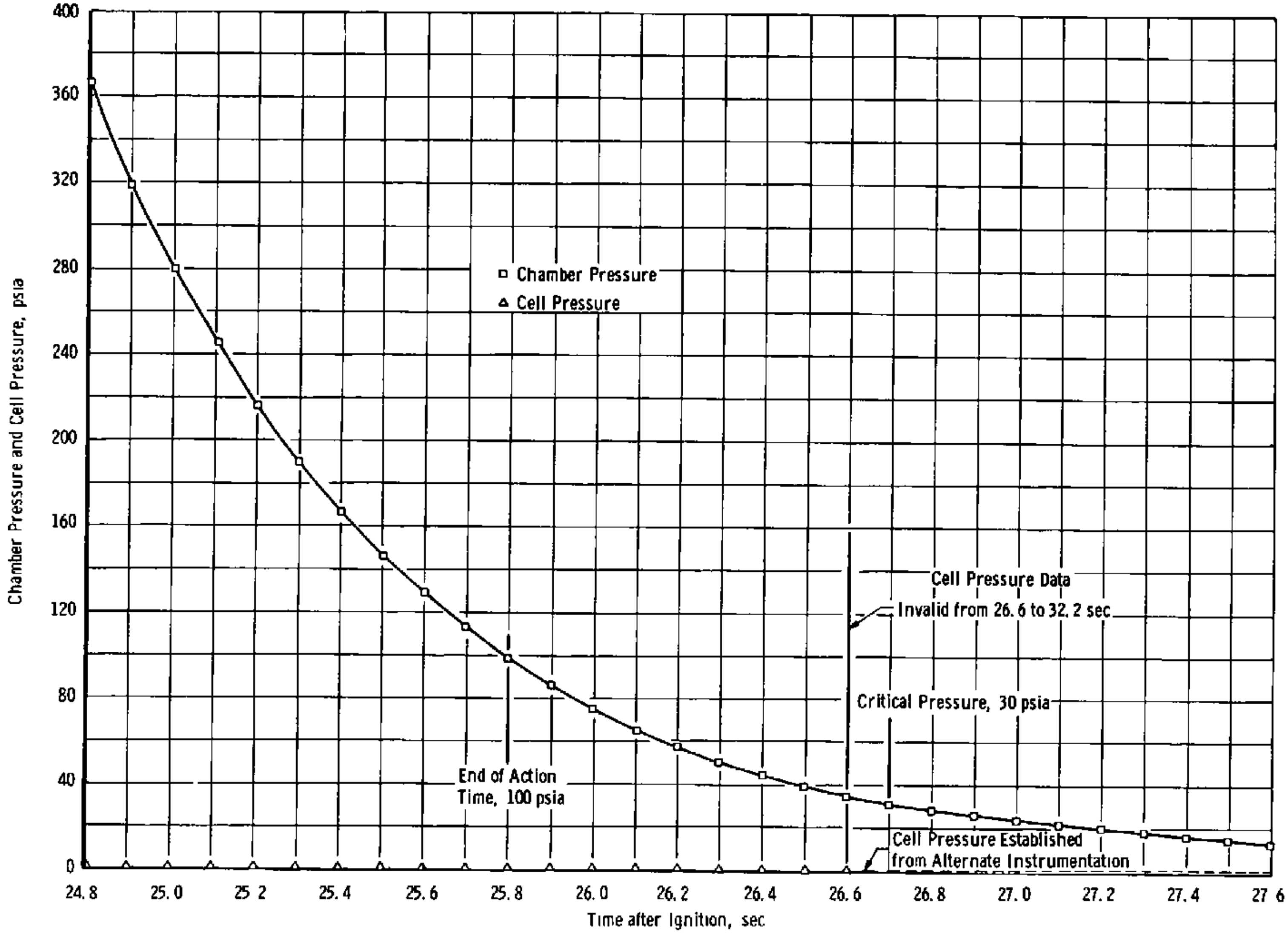



**Fig. 7 Low Range Chamber Pressure from Diffuser Breakdown to Chamber Pressure Equal to 12 psia**

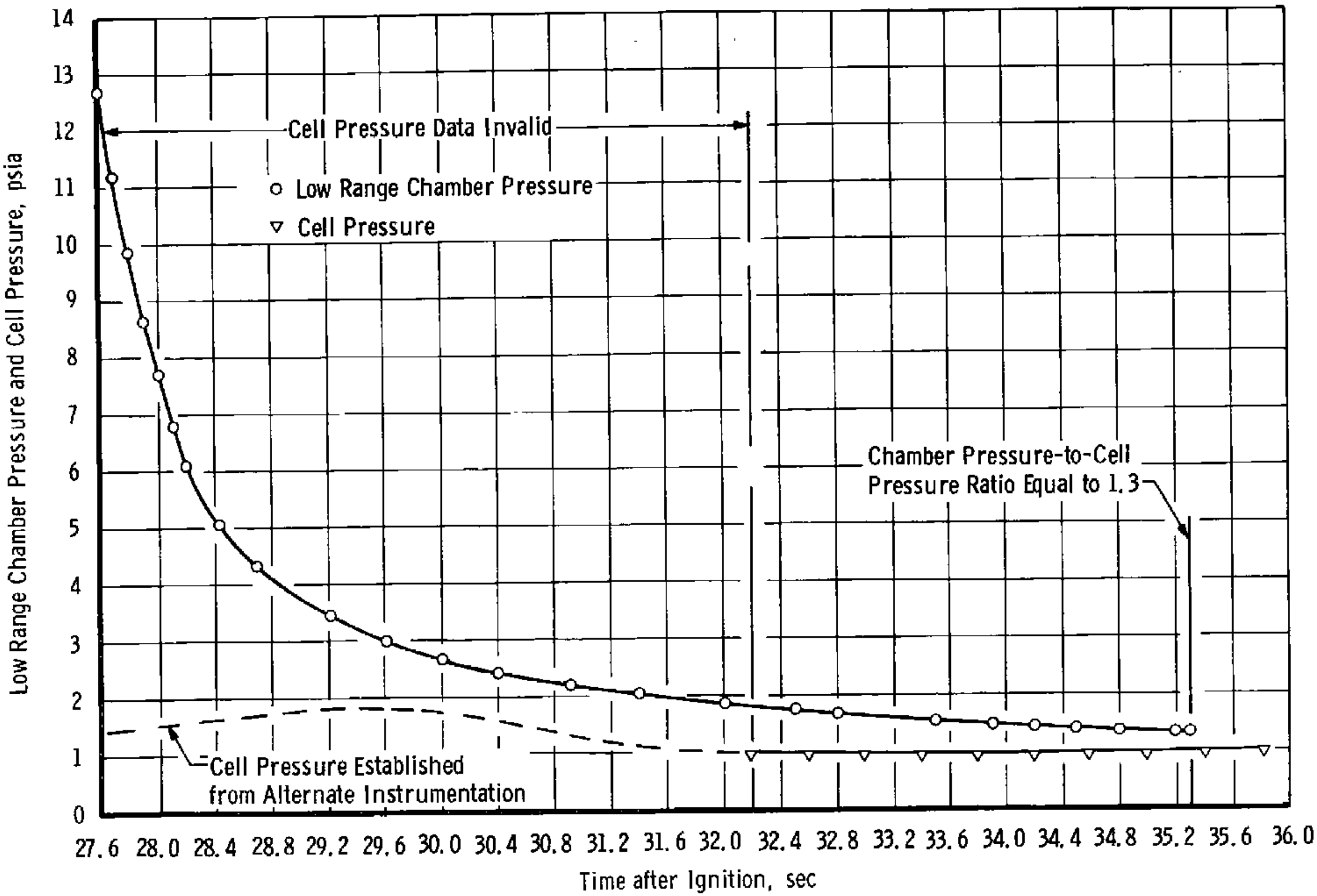
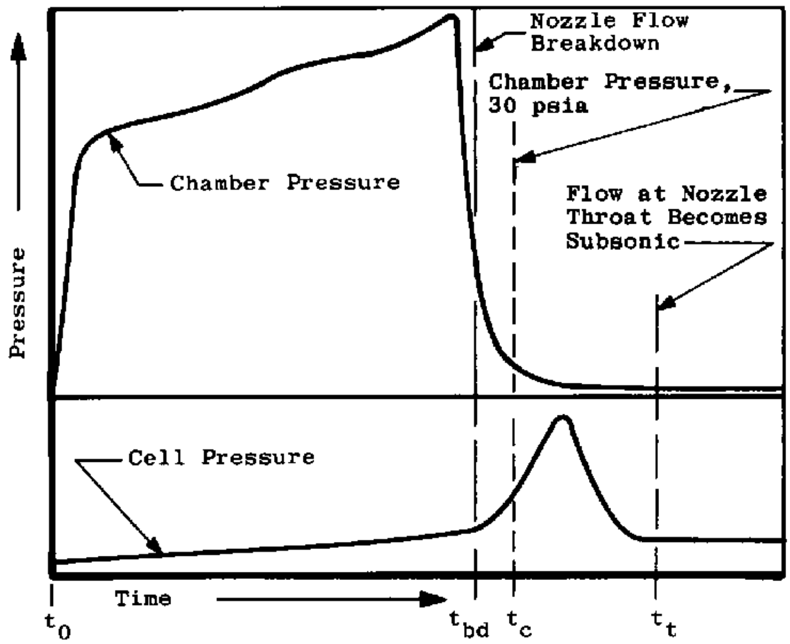



Fig. 8 Low Range Chamber Pressure from 12 psia to Chamber Pressure-to-Cell Pressure Ratio Equal to 1.3



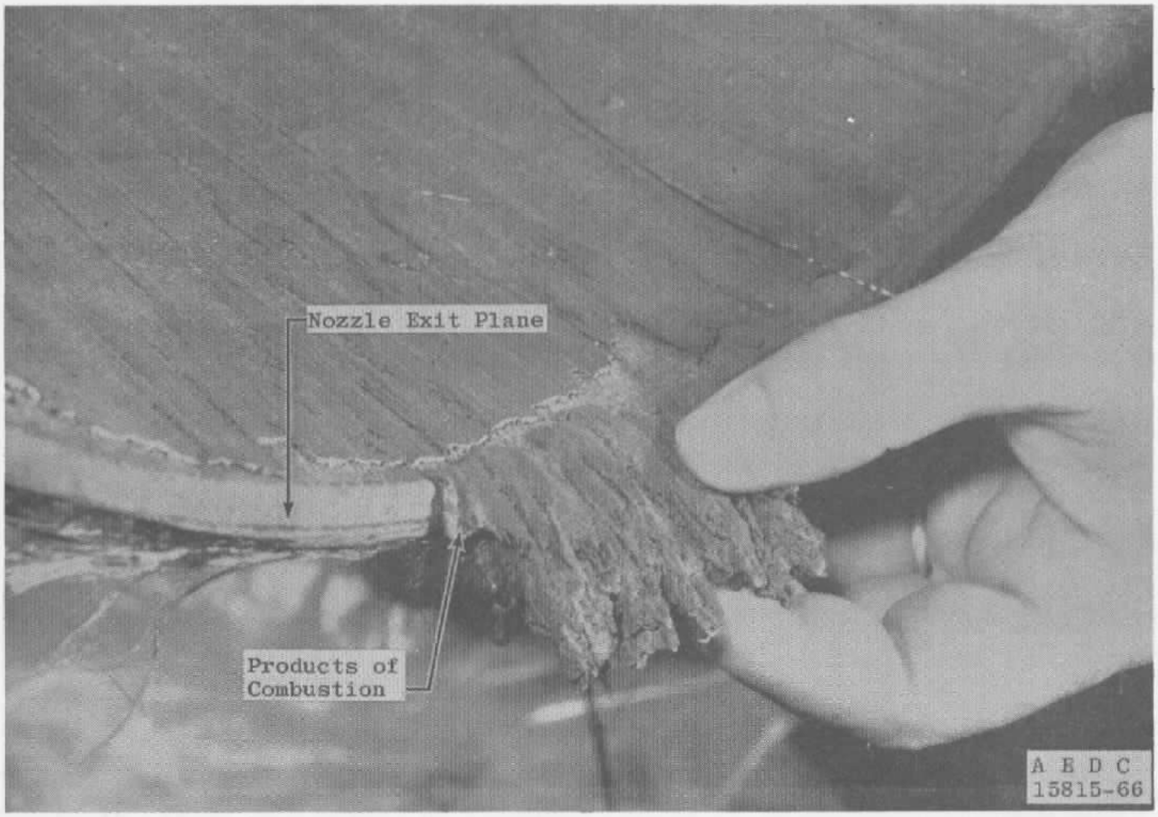

$$I_{vac_{total}} = \int_{t_0}^{t_{bd}} F\,dt + A_{ex(avg)} \int_{t_0}^{t_{bd}} P_{cell}\,dt + c_f \quad A_{th(post)} \int_{t_{bd}}^{t_t} P_{ch}\,dt$$

$$I_{vac_{critical}} = \int_{t_0}^{t_{bd}} F\,dt + A_{ex(avg)} \int_{t_0}^{t_{bd}} P_{cell}\,dt + c_f \quad A_{th(post)} \int_{t_{bd}}^{t_c} P_{ch}\,dt$$

$$I_{vac_{action}} = \int_{t_a}^{t_{bd}} F\,dt + A_{ex(avg)} \int_{t_a}^{t_{bd}} P_{cell}\,dt + c_f \quad A_{th(post)} \int_{t_{bd}}^{t_a} P_{ch}\,dt$$

where: $c_f = \dfrac{F_{measured} + P_{cell} \cdot A_{ex(post)}}{P_{ch} \cdot A_{th(post)}}$ established from data during the time interval from 22.45 to 23.45 sec after ignition

Fig. 9 Definition of Vacuum Total and Critical Impulse



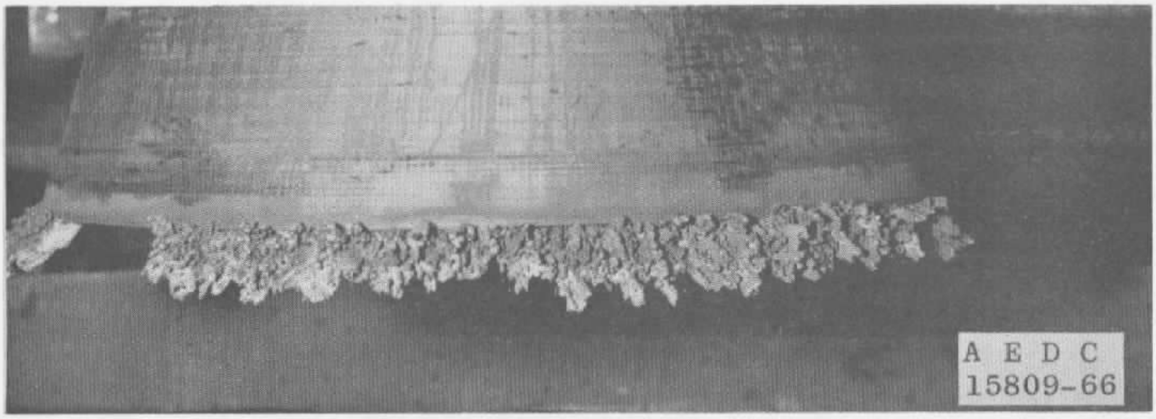
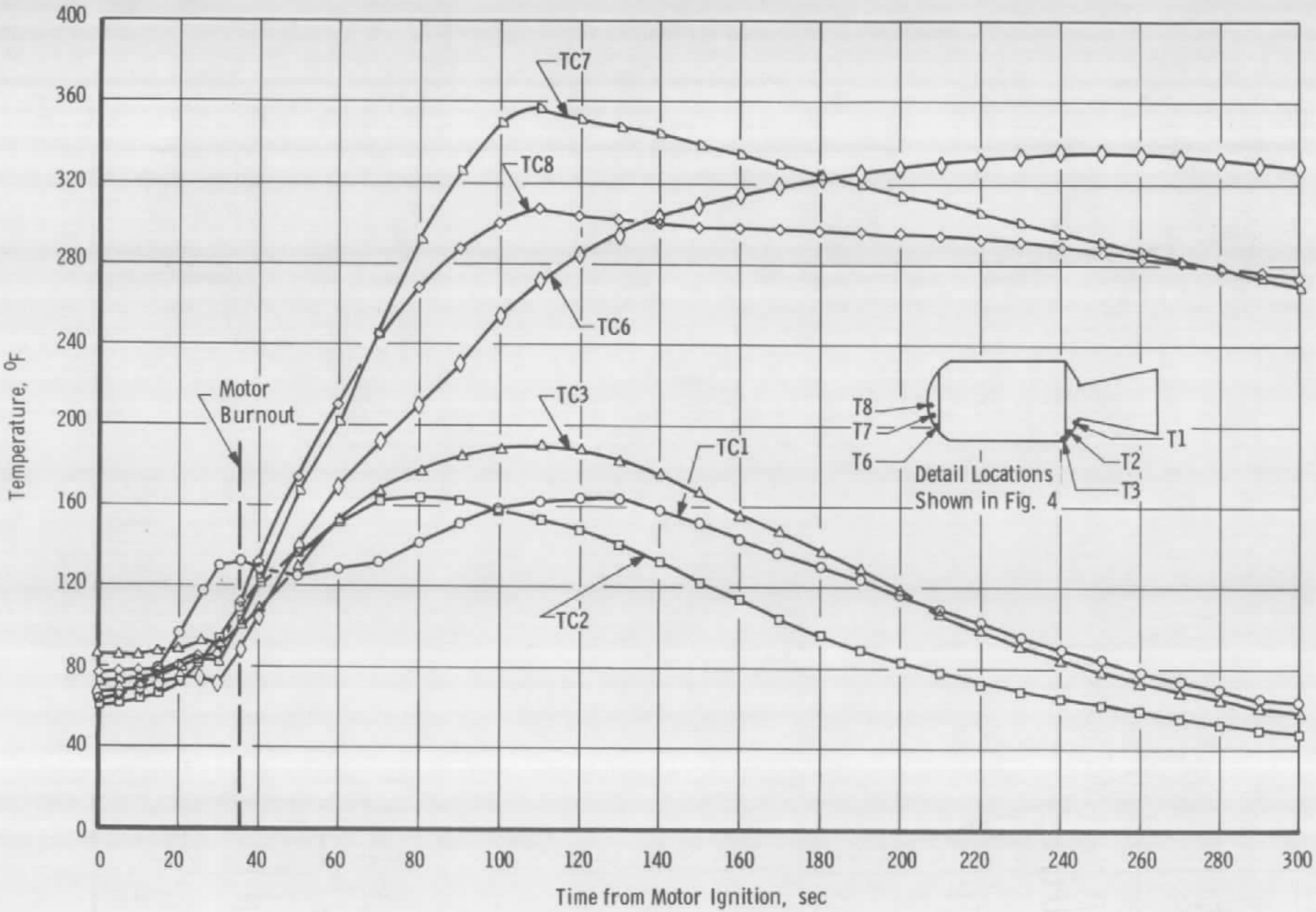
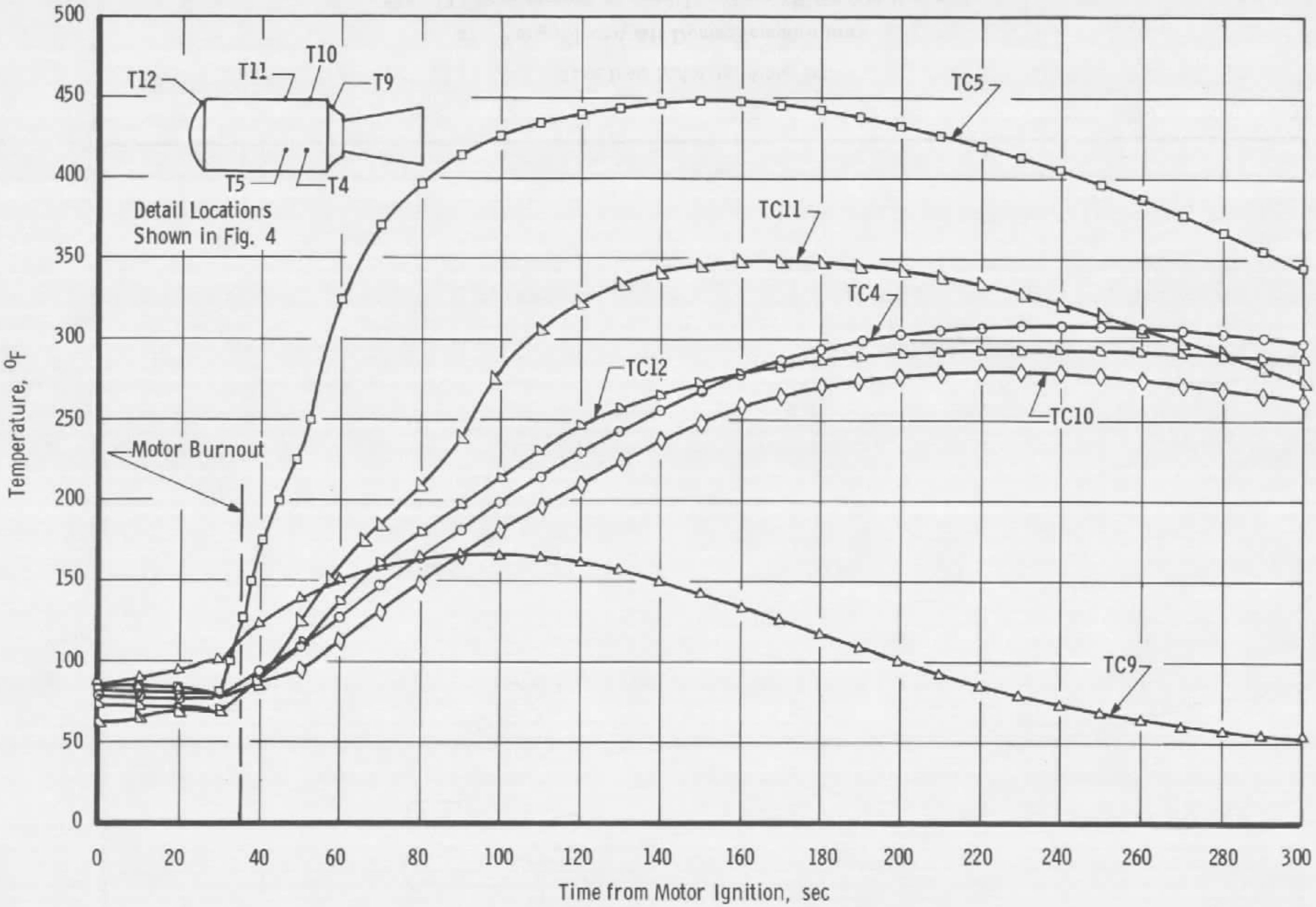




**Fig. 10 Detail of Products of Combustion Deposited on the Nozzle Exit**




a. Forward and Aft Dome Temperatures

**Fig. 11 Temperature History for Alcor 1B Rocket Motor**




b. Temperature on the Cylindrical Portion of the Chamber

Fig. 11 Concluded

## TABLE I
## INSTRUMENTATION

| Parameter | Estimated System Accuracy (2σ) | | Measuring Device | Range of Measuring Device | Recording Device | Method of System Calibration |
|---|---|---|---|---|---|---|
| | Steady-State Operating Level | Integral, percent | | | | |
| Axial Force, $lb_f$ | ±0.32 percent | --- | Bonded Strain-Gage-Type Load Cells (2 Used) | 0 to 13,200 $lb_f$ | Millivolt-to-Frequency or Digital Converter onto Magnetic Tape | Deadweight |
| Total Impulse, $lb_f$-sec | --- | ±0.32 | | | | |
| Motor Chamber Pressure, psia | ±0.46 percent | --- | Bonded Strain-Gage-Type Transducers (2 Used) | 0 to 650 psia | | Electrical |
| Chamber Pressure Integral, psia-sec | --- | ±0.44 | | | | |
| Low Range Chamber Pressure, psia | ±1 percent | --- | | 0 to 30 psia | | |
| Low Range Pressure, psia | ±2 percent | --- | | 0 to 15 psia | | |
| Test Cell Pressure, psia | ±1.86 percent | --- | Unbonded Strain-Gage-Type Transducers (2 Used) | 0 to 1 psia | | |
| Test Cell Pressure Integral, psia-sec | --- | ±1.86 | | | | |
| Time Interval, msec | ±5 msec | --- | Synchronous Timing Line Generator | --- | Photographically Recording Galvanometer-Type Oscillograph | Compare with 60 cps |
| Temperature, °F | ±5°F | --- | Chromel®-Alumel,® Iron-Constantan Thermocouples | 0 to 600°F | Digital Millivolt-meter onto Magnetic Tape | Known Millivolt Source and NBS Temperature Tables |
| Weight, $lb_m$ | ±0.031 $lb_m$ | --- | Beam Balance Scales | 0 to 3000 $lb_m$ | Visual Readout | Periodic Deadweight Calibration |

**TABLE II**
**SUMMARY OF MOTOR PERFORMANCE**

| | |
|---|---|
| Test Number | RC0638-01 |
| Test Date | 7/20/66 |
| Motor Serial Number | STV097 |
| Simulated Altitude at Ignition, ft | 106,000 |
| Average Simulated Altitude (Based on Action Time), ft | 100,000 |
| Average Spin Rate during Firing, rpm | 304.3 |
| Ignition Delay Time ($t_d$), sec | 0.035 |
| Action Time ($t_a$), sec | 25.627 |
| Critical Time ($t_c$), sec | 26.692 |
| Total Burn Time ($t_t$), sec | 35.30 |
| Maximum Thrust (vac), $lb_f$ | 12,963 |
| Maximum Chamber Pressure, psia | 520.11 |
| Measured Impulse (from Ignition until Diffuser Breakdown), $lb_f$-sec | |
| Average of Four Channels of Data | 248,814 |
| Maximum Deviation from Average, percent | +0.006 |
| Chamber Pressure Integral (from Ignition until Diffuser Breakdown), psia-sec | |
| Average of Two Channels of Data | 10,401.4 |
| Maximum Deviation from Average, percent | +0.052 |
| Cell Pressure Integral (from Ignition until Diffuser Breakdown), psia-sec | |
| Average of Four Channels | 3.47010 |
| Maximum Deviation from Average, percent | -1.20 |
| Vacuum Impulse (Based on Time Interval from Ignition until Diffuser Breakdown), $lb_f$-sec | 249,592 |
| Vacuum Thrust Coefficient ($c_f$) (Based on 1-sec Data 22.45 to 23.45 sec after Ignition and Post-Fire Throat Area) | 1.738 |
| Chamber Pressure Integral (from Diffuser Breakdown until Chamber Pressure-to-Cell Pressure Ratio Equals 1.3), psia-sec | 280.26 |
| Chamber Pressure Integral (from Diffuser Breakdown until Chamber Pressure Equals 30 psia), psia-sec | 243.60 |
| Chamber Pressure Integral (from Diffuser Breakdown until Chamber Pressure Equals 100 psia), psia-sec | 190.5 |
| Vacuum Total Impulse (Based on $t_t$), $lb_f$-sec* | 256,616 |
| Vacuum Critical Impulse (Based on $t_c$), $lb_f$-sec* | 255,696 |
| Vacuum Action Impulse (Based on $t_a$), $lb_f$-sec* | 254,366 |
| Vacuum Specific Impulse (Based on Vacuum Total Impulse and Consumed Weight), $lb_f$-sec/$lb_m$ | 279.12 |
| Average Vacuum Thrust Coefficient, $c_f$, (Based on Total Burn Time ($t_t$) and Average Pre- and Post-Fire Throat Area) | 1.727 |

*Vacuum total, critical, and action impulse defined in Fig. 9

## TABLE III
## SUMMARY OF MOTOR PHYSICAL DIMENSIONS

| | |
|---|---|
| Test Number | RC0638-01 |
| Test Date | 7/20/66 |
| Motor Serial Number | STV097 |
| Pre-Fire Motor Assembly Weight (Includes Igniter), $lb_m$ | 1005.226 |
| Post-Fire Assembly Weight (Includes Igniter), $lb_m$ | 85.856 |
| Expended Mass (Includes Igniter Propellant) (AEDC), $lb_m$ | 919.370 |
| Manufacturer's Stated Propellant Weight ($W_p$) (Includes Igniter Propellant), $lb_m$ | 913.7 |
| Nozzle Throat Area, in.$^2$ | |
| Pre-Fire | 13.403 |
| Post-Fire | 14.420 |
| Percent Change from Pre-Fire Measurement | +7.588 |
| Average | 13.9115 |
| Nozzle Exit Area*, in.$^2$ | |
| Pre-Fire | 218.568 |
| Post-Fire | 216.968 |
| Percent Change from Pre-Fire Measurement | -0.73 |
| Average | 217.768 |
| Nozzle Area Ratio, A/A* | |
| Pre-Fire | 16.31 |
| Post-Fire | 15.05 |
| Average | 15.654 |

*Exhaust products removed before measurements

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|---|---|
| 1 ORIGINATING ACTIVITY (Corporate author)<br>Arnold Engineering Development Center<br>ARO, Inc., Operating Contractor,<br>Arnold Air Force Station, Tennessee | 2a REPORT SECURITY CLASSIFICATION<br>UNCLASSIFIED<br>2b GROUP N/A |

3 REPORT TITLE
PERFORMANCE OF THE AEROJET-GENERAL CORPORATION ALCOR 1B SOLID-PROPELLANT ROCKET MOTOR UNDER THE COMBINED EFFECTS OF ROTATIONAL SPIN AND SIMULATED ALTITUDE

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)
N/A

5 AUTHOR(S) (Last name, first name, initial)
Bahor, L. R., ARO, Inc.

| 6 REPORT DATE | 7a TOTAL NO OF PAGES | 7b NO OF REFS |
|---|---|---|
| October 1966 | 35 | 3 |

| | |
|---|---|
| 8a CONTRACT OR GRANT NO AF40(600)-1200 | 9a ORIGINATOR'S REPORT NUMBER(S)<br>AEDC-TR-66-186 |
| b. System 627A | |
| c Program Element 64406124 | 9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report)<br>N/A |
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13 ABSTRACT

One Aerojet-General Corporation, Alcor 1B, solid-propellant rocket motor was successfully tested at an average simulated altitude of 100,000 ft while spinning about its axial centerline at an average spin rate of 304.3 rpm. The objective of this test was to evaluate the ballistic performance, tailoff characteristics, and structural integrity of the flightweight motor assembly under the combined effects of rotational spin and near-vacuum environment. The vacuum total impulse was 256,616 $lb_f$-sec; the vacuum specific impulse, based on the vacuum total impulse and pre- and post-fire weight difference, was 279.12 $lb_f$-sec/$lb_m$. The total burn time, defined as the time interval from the application of voltage to the igniter to the time when the chamber pressure-to-cell pressure ratio is 1.3, was 35.30 sec.

| 14 KEY WORDS | LINK A ROLE | LINK A WT | LINK B ROLE | LINK B WT | LINK C ROLE | LINK C WT |
|---|---|---|---|---|---|---|
| solid propellants | | | | | | |
| performance | | | | | | |
| rocket motor | | | | | | |
| spin | | | | | | |
| altitude simulation | | | | | | |
| structural integrity | | | | | | |
| pressure | | | | | | |

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